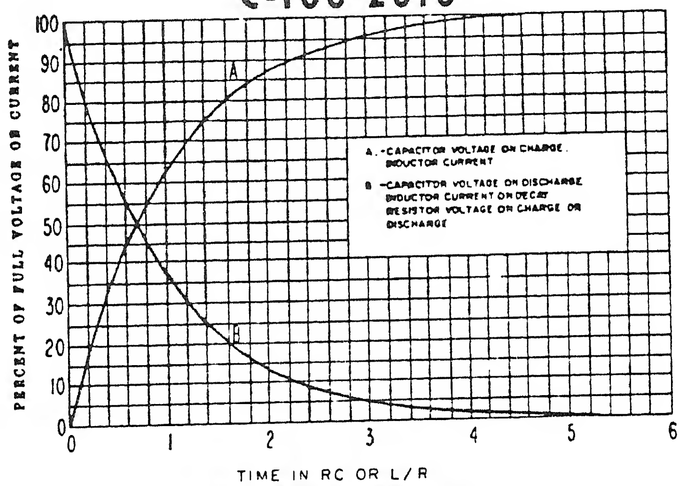
STUDENT GUIDE

FOR

ADVANCED FIRST-TERM AVIONICS COURSE

CLASS A1

C-100-2010



UNIT I

CNTT-M1681

PREPARED BY

NAVAL AIR TECHNICAL TRAINING CENTER

NAVAL AIR STATION MEMPHIS

MILLINGTON TENNESSEE

PREPARED FOR

CHIEF OF NAVAL TECHNIAL TRAINING

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FOREWORD

The purpose of this "Student's Guide" is to assist you in completing the "Mathematics of a-c theory and d-c theory," Unit I, of the Advanced First-Term Avionics Course. The proper use of this guide will increase your abilities in the above mentioned areas, while building a basis upon which your future training will be built.

The table of contents lists the page numbers for safety notices, notetaking sheets, information sheets, and references that will further enhance your abilities and skills as an aviation electronics technician.

SAFETY NOTICE

As a Navy electronics technician, you will be required to perform safe and efficient maintenance on various types of electonic equipment. Not only your life, but the lives of many others will depend on your being safety conscious at all times. It is the responsibility of all Navy and Marine Corps personnel to prevent accidents. This can be done if everyone develops and practices conscientious safety habits and observes all precautions when performing maintenance of any type. Always remember:

SAFETY CANNOT BE OVERSTRESSED!!!!!!!

HOW TO USE THIS STUDENT'S GUIDE

This "Student's Guide" has been prepared for you to use while you are attending the Advanced First-Term Avionics Course (Class A1). Ample space has been provided for taking notes on the required lesson information. Remember when you are in class, the information being provided by the instructor is information you will need in performing you Navy job.

This volume contains the following:

1. Notetaking sheets containing lesson topic outlines, illustrations, and ample space for personal notetaking.

2. Information sheets to provide information pertinent to your training.

GOOD LUCK! Learn as much as you can!

UNIT 1 CLASS SCHEDULE

Unit I is two weeks long and starts the morning of the first day. The periods run from 1thru 76, with the last period finishing half-way through the fifth day of the second week.

The schedule is as follows:

TOPIC NO.	TYPE	PERIOD	TOPIC
FIRST WEEK			
First Day			
1.1	Class	1	Course Introduction
		2	
		3	
		4	
1.2	Class	5	Exponents and Radicals
		6	
		7	
		8	
Second Day			
1.3	Class	9	Powers of Ten and Conversion of Electrical Units
		10	
		11	
1.4	Class	12	Algebraic Fundamentals
		13	
		14	
		15	
		16	
Third Day			
1.5	Class	17	Linear Equations
		18	
		19	
		20	
1.6	Class	21	Formula
		22	
		23	
		24	

TOPIC NO.	TYPE	PERIOD	TOPIC
Fourth Day			
1.7	Class	25	Source Characteristics and Voltage Dividers
		26	
		27	
		28	
		29	
		30	
		31	
		32	
Fifth Day			
	Class	33	Unit/Module Test; Criterion Test/Written Exam
		34	
		35	
1.8	Class	36	Bridge Circuits
		37	
		38	
		39	(Drill)
		40	(Drill)
SECOND WEEK			
First Day			
1.9	Class	41	Capacitance and RC Time
		42	
		43	
		44	
		45	
		46	(Drill)
		47	(Drill)
		48	(Drill)
Second Day			
1.10	Class	49	Inductance and LR Time
		50	
		51	
		52	
1.11	Class	53	Trigonometric Functions and Vector Algebra
		54	
		55	
		56	

TOPIC NO.	TYPE	PERIOD	TOPIC
Third Day			
1.12	Class	57	Series A-C Circuits
		58	
		59	
		60	
		61	
		62	(Drill)
		63	(Drill)
		64	(Drill)
Fourth Day			
1.13	Class	65	Parallel A-C Circuits
		66	
		67	
		68	
		69	
		70	(Drill)
		71	(Drill)
		72	(Drill)
Fifth Day			
	Class	73	Unit/Module Test: Criterion Test/Written Examination
		74	
		75	
		76	

UNIT I HOMEWORK SCHEDULE

Homework is MANDATORY. In Unit I, homework is assigned with each individual lesson topic. Homework is due on the following morning after the lesson is given. Each assignment sheet will be checked by an instructor for correctness and completion. Information sheets assigned as lesson topics are covered and are considered homework. Failure to complete assigned homework may result in disciplinary action.

Assignment Sheet	Period Due
1.2.1A	9
1.2.2A	9
1.3.1A	17
1.3.2A	17
1.4.1A	17
1.4.2A	17
1.5.1A	25
1.5.2A	25
1.6.1A	25
1.6.2A	25
1.7.1A	33
1.7.2A	33
1.8.1A	41
1.8.2A	41
1.9.1A	49
1.9.2A	49
1.10.1A	57
1.10.2A	57
1.11.1A	57
1.11.2A	57

Assignment Sheet	Period Due
1.12.1A	65
1.12.2A	65
1.13.1A	73
1.13.2A	73

UNIT LEARNING OBJECTIVES

TERMINAL OBJECTIVE:

0.0. This indoctrination lesson is designed to provide a general knowledge of the Advanced First-Term Avionics Training Program, the chain of command, rules, regulations, and responsibilities of the avionics technician. Throughout the course, particular emphasis will be placed on the fundamentals of accident prevention, in accordance with OPNAVINST 5101.2 series. Indoctrination information will not be tested.

1.0. SOLVE problems related to electronic circuits, using basic mathematics, algebra, and trigonometry. A formula sheet, trigonometric tables, and a Universal Time Constant Chart will be provided. Performance must be in accordance with mathematical principles outlined in Mathematics, Vol. I, NAVPERS 10069-series, Mathematics, Vol. III, NAVPERS 10073-series, Basic Electronics, Vol. I, NAVPERS 10087-series, and Basic Electricity, NAVPERS 10086-series. Performance will be measured by a written multiple-choice examination.

ENABLING OBJECTIVES:

1.1. SOLVE problems involving addition, subtraction, multiplication, and division of radicals and exponents, using the laws of exponents. Response must be in accordance with Mathematics, Vol. I, NAVPERS 10069-series. Performance will be measured by a written multiple-choice examination.

1.2. SOLVE problems involving the addition, subtraction, mulitplication, division, evaluation, and simplification of algebraic expressions. Response must be in accordance with Mathematics, Vol. I, NAVPERS 10069-series. Performance will be measured by a written multiple-choice examination. A formula sheet will be provided.

1.3. SOLVE for the variables in simultaneous linear equations, using the principles of matrix algebra. Responses must be in accordance with Mathematics, Vol. III, NAVPERS 10073-series. Performance will be measured by a written multiple-choice examination. A formula sheet will be provided.

1.4. SOLVE for total capacitance, RC time, current, and voltage values of a simple RC switching circuit. Response must be in accordance with Basic Electricity, NAVPERS 10086-series. Performance will be measured by a written multiple-choice examination. A formula sheet and a Universal Time Constant Chart will be provided.

1.5. SOLVE for total inductance, L/R time, current, and voltage values of a simple L/R switching circuit. Response must be in accordance with Basic Electricity, NAVPERS 10086-series. Performance will be measured by a written multiple-choice examination. A formula sheet and a Universal Time Constant Chart will be provided.

1.6. SOLVE for unknown current, voltage, and resistance values of electronic circuits containing source characteristics and voltage dividers. Response must be in accordance with Basic Electricity, NAVPERS 10086-series. Performance will be measured by a written multiple-choice examination. A formula sheet will be provided.

1.7. SOLVE for unknown vlaues of current, voltage, reactance, and power in series and parallel a-c circuits. Response must be in accordance with Basic Electricity, NAVPERS 10086-series. Performance will be measured by a written multiple-choice examination. A formula sheet and trigonometric tables will be provided.

1.8. SOLVE for unknown values of current, voltage, reactance, frequency, badwidth, and circuit "Q", in series and parallel resonant circuits. Response will be in accordance with Basic Electronics, Vol. I, NAVPERS 10087-series. Performance will be measured by a written multiple-choice examination. A formula sheet and trigonometric table will be provided.

TABLE OF CONTENTS

INFORMATION SHEET 1.1.1I

COURSE INTRODUCTION

INTRODUCTION

You are entering what is probably the finest, most modern course of electronics in the Navy, and quite possibly, the entire military establishment. To assist your daily activities while a student at AFTA, the course is providing this information sheet for your use.

REFERENCES

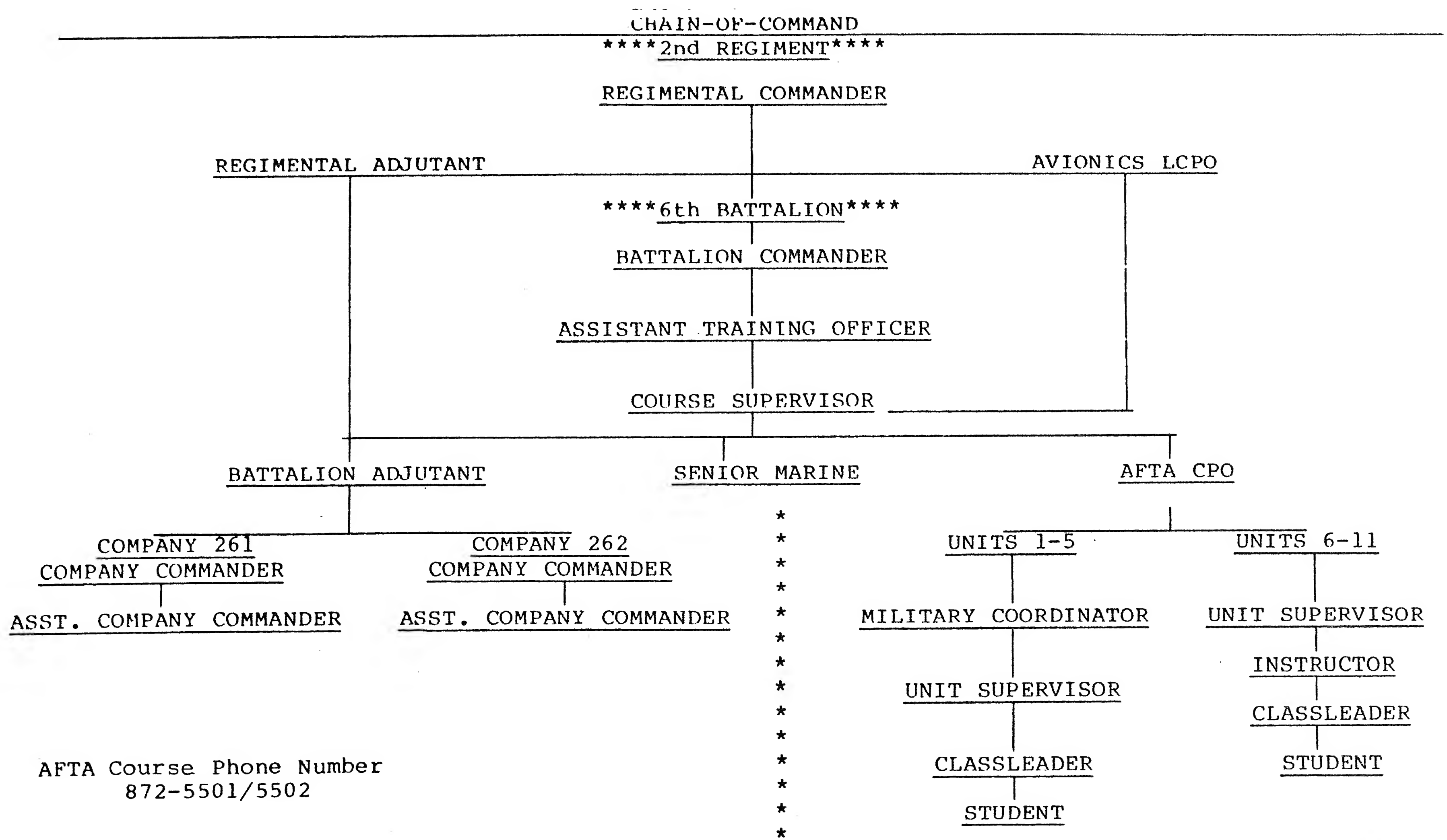
1. Chain of Command. AFTA Training Officer's memo, 3 January 1984.

2. Noon class /Night class Schedule. Military Coordinator, Unit 1-5, 12 December 1983.

INFORMATION

FIGURE 1. Chain of Command

FIGURE 2. Noon class /Night class Schedule



AFTA Course Phone Number
872-5501/5502

Figure 1 -- Chain-of-Command

(TRAINING ONLY)

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY
WEEK 1 - 1120 - 1150	NOON CLASSES - YOUR ASSIGNED CLASSROOM
WEEK 2 - 1120 - 1150 1530 - 1730	NOON CLASSES - YOUR ASSIGNED CLASSROOM NIGHT CLASSES - ROOM 178, NIGHT BEFORE TEST
WEEK 3 - 1120 - 1150	NOON CLASSES - YOUR ASSIGNED CLASSROOM
WEEK 4 - 1120 - 1150	NOOM CLASSES - YOUR ASSIGNED CLASSROOM
WEEK 5 - 1120 - 1150	NOON CLASSES - YOUR ASSIGNED CLASSROOM
WEEK 6 - 1120 - 1150 1530 - 1730	NOON CLASSES - YOUR ASSIGNED CLASSROOM NIGHT CLASSES - ROOM 176, NIGHT BEFORE TEST
WEEK 7 - 1120 - 1150 1530 - 1730	NOON CLASSES - YOUR ASSIGNED CLASSROOM NIGHT CLASSES - ROOM 159, NIGHT BEFORE TEST
WEEK 8 - 1120 - 1150 1530 - 1730	NOON CLASSES - YOUR ASSIGNED CLASSROOM NIGHT CLASSES - ROOM 160, NIGHT BEFORE TEST
WEEK 9 - 1120 - 1150	NOON CLASSES - YOUR ASSIGNED CLASSROOM
WEEK 10- 1120 - 1150	NOON CLASSES - YOUR ASSIGNED CLASSROOM

Figure 2: Noon/Night Class Schedule

NOTETAKING SHEET 1.2.1N

EXPONENTS AND RADICALS

REFERENCE:

Mathematics, Vol. I, NAVPERS 10069 series, Chapter 7, pages 65-71.

NOTETAKING OUTLINE

A. Terms and definitions

1. Factor - One of two or more numbers that, when multiplied together, produce a given quantity called a product.

2. Power - The product of a factor multiplied by itself one or more times.

3. Exponent - A small number used to indicate the power to which a number is raised.

4. Root - A number or quantity that, when multiplied by itself a specified number of times, will produce a given number.

B. Rules of Exponents

1. Multiplication

2. Division

3. Power of a power

4. Power of a product

5. Power of a quotient

6. Extracting the root of a power

C. Special Exponents

1. Zero exponents

2. Negative exponents

3. Fractional exponents

NOTETAKING SHEET 1.3.1N

POWERS OF TEN AND CONVERSION OF ELECTRICAL UNITS

REFERENCE:

1. Mathematics, Vol. I, NAVPERS 10069-series.

2. Basic Mathematics for Electronics, Fifth Edition, Cooke, Adams, Dell; McGraw-Hill, 1982.

A. Powers of Ten

1. Purpose - Used to express any number as an equivalent number times some power of ten.

2. Multiples of Ten

B. Scientific notation

1. Definition - Numerical values expressed as a number between 1 and 10 times the appropriate power of ten.

2. Expressing numbers in scientific notation

C. Addition and Subtraction

D. Multiplication and division

E. Combined multiplication and division

F. Metric prefixes:

G. Conversion of Prefixes

H. Computations with Units

INFORMATION SHEET 1.3.1I

CONVERSION TABLE OF ELECTRICAL UNITS

NUMERICAL VALUE	PREFIX	ABBREVIATION	POWER OF 10
.000 000 000 001	Pico	p	10^{-12}
.000 000 001	Nano	n	10^{-9}
.000 001	Micro	µ	10^{-6}
.001	Milli	m	10-3
1	Basic Unit	None	10^{0}
1,000	Kilo	k	10^{3}
1,000,000	Mega	M	10^{6}
1,000,000,000	Giga	G	10^{9}
1,000,000,000,000	Tera	T	10^{12}

NOTETAKING SHEET 1.4.1N

ALGEBRAIC FUNDAMENTALS

REFERENCES

1. Mathematics, Vol. I, NAVPERS 10069-C 1966, Chapter 9 & 10. pages 98 - 119.

2. Mathematics, Vol. III, NAVPERS 10073-series.

3. Basic Mathematics for Electronics, Fifth Edition, Cooke, Adams, Dell; McGraw-Hill, 1982.

NOTETAKING OUTLINE

A. Terminology

1. Literals - Letters or symbols that are used to represent numbers or quantities.

2. Algebraic Expression - Expresses or represents a number or quantity by the signs and symbols of algebra.

3. Coefficient - Usually considered to be the numerical part of an algebraic term, but may be of any one or any combination of the factors of a term.

4. Term - Any algebraic expression or portion of an expression <u>NOT</u> separated by a plus (+) or minus (-) sign.

5. Evaluation - Means to find the numerical value of an algebraic expression.

B. Signs of Operation

C. Signs of Grouping

D. Addition and Subtraction

E. Multiplication

1. Monomials

2. Polynomial by a monomial

3. Polymonial by a polynomial

F. Divison

1. Monomials

2. Polynomial by a monomial

G. Factoring

INFORMATION SHEET 1.4.1I

ALGEBRAIC FUNDAMENTALS

INTRODUCTION

The purpose of this information sheet is to provide you with additional information pertaining to lesson 1.2. Use of this information sheet will enhance your knowledge of the rules of operation with signed numbers.

REFERENCE: <u>Mathematics</u>, Vol I, NAVPERS 10069C-series

INFORMATION

<u>RULES FOR OPERATIONS WITH SIGNED NUMBERS</u>

A. Addition.

1. Like signs: Find the <u>sums</u> of the absolute values and keep the common sign.

   Examples:

$$\begin{array}{r} +1 \\ +1 \\ \hline +2 \end{array} \quad \begin{array}{r} -1 \\ -1 \\ \hline -2 \end{array} \quad \begin{array}{r} +3 \\ +4 \\ \hline +7 \end{array} \qquad \begin{array}{r} -3 \\ -4 \\ \hline -7 \end{array} \qquad \begin{array}{l} (+1)+(+1) = +2 \\ (-3)+(-4) = -7 \end{array}$$

2. Unlike signs: Find the difference between the absolute values and take the sign of the larger absolute value.

   Examples:

$$\begin{array}{r} +3 \\ -1 \\ \hline +2 \end{array} \quad \begin{array}{r} -3 \\ +1 \\ \hline -2 \end{array} \quad \begin{array}{r} +1 \\ -3 \\ \hline -2 \end{array} \qquad \begin{array}{r} -1 \\ +3 \\ \hline +2 \end{array} \qquad \begin{array}{l} (-3)+(+1) = -2 \\ (-1)+(+3) = +2 \end{array}$$

3. Adding more than two signed numbers: Combine absolute values which have like signs using the rule for adding like signs as stated above. Then, when necessary, use the rule for unlike signs.

   Examples:

$$\begin{array}{r} +2 \\ +2 \\ +3 \\ \hline +7 \end{array} \quad \begin{array}{r} -2 \\ -2 \\ -3 \\ \hline -7 \end{array} \quad \begin{array}{r} -3 \\ +2 \\ -4 \\ \hline \end{array} \text{ combine to } \begin{array}{r} -7 \\ +2 \\ \hline -5 \end{array} \qquad (+3)+(-2)+(+4)=(+7)+(-2)=+5$$

B. Subtraction.

1. Only one rule is applied to subtraction of signed numbers: Change the sign of the subtrahend to the opposite sign and proceed as in addition.

   Examples:

   $$\begin{array}{r} +2 \\ \underline{+2} \\ \underline{} \end{array} \text{ change to } \begin{array}{r} +2 \\ \underline{-2} \\ 0 \end{array} \qquad \begin{array}{r} +2 \\ \underline{-2} \\ \underline{} \end{array} \text{ change to } \begin{array}{r} +2 \\ \underline{+2} \\ +4 \end{array} \qquad \begin{array}{l} (+3)-(+5)=(+3)+(-5)=-2 \\ (+3)-(-5)=(+3)+(+5)=+8 \end{array}$$

C. Multiplication.

1. Multiplication with ONLY TWO factors.

   a. Like signs: Find the product of the absolute values and give the answer a positive sign.

      Examples:

      $(+2) \times (+3) = +6$ $\qquad$ $(-2) \times (-3) = +6$

   b. Unlike signs: Find the product of the absolute values and give the answer a negative sign.

      Examples:

      $(+2) \times (-3) = -6$ $\qquad$ $(-2) \times (+3) = -6$

2. Multiplication with MORE THAN TWO factors: Find the product of the absolute values and the answer will be:

   a. Positive if the sign of all factors are positive or if there is an even number of factors with a negative sign.

   b. Negative if there is an odd number of factors with a negative sign.

   c. Examples:

      $(+2) \times (+3) \times (+4) = +24$ $\qquad$ $(+2) \times (-3) \times (-4) = +24$

      $(+2) \times (+3) \times (-4) = -24$ $\qquad$ $(-2) \times (-3) \times (-4) = -24$

D. Division.

1. Like signs: Find the quotient of the absolute values and give the answer a positive sign.

Examples:

$\frac{+6}{+3} = +2$ $\frac{-6}{-3} = +2$ $(+9) \div (+3) = +3$ $(-9) \div (-3) = +3$

2. Unlike signs: Find the quotient of the absolute values and give the answer a negative sign.

Examples:

$\frac{+6}{-3} = -2$ $\frac{-6}{+3} = -2$ $(+9) \div (-3) = -3$ $(-9) \div (+3) = -3$

INFORMATION SHEET 1.4.2I

ALGEBRAIC FUNDAMENTALS

INTRODUCTION

The purpose of this information sheet is to provide you with additional information pertaining to lesson 1.2. Use of this information sheet will enhance the student's knowledge of the rules of operations with fractions.

REFERENCE: Basic Mathematics for Electronics, N. M. Cooke, 1960

INFORMATION

RULES FOR OPERATION WITH FRACTIONS

A. Addition.

1. Find a common denominator if necessary. (Fractions must have common denominators before addition can be done.)

2. Add the numerators and write their sum over the common denominator.

3. Reduce the fraction to its lowest terms.

4. Examples:

$$\begin{array}{l} 3/8 \\ \underline{1/8} \\ 4/8 = 1/2 \end{array} \qquad \begin{array}{l} 1/2 \\ \underline{3/12} \\ \underline{} \end{array} \text{ change to } \begin{array}{l} 6/12 \\ \underline{3/12} \\ 9/12 = 3/4 \end{array}$$

$1/4+2/4=3/4$

$2/3 + 3/4 = 8/12 + 9/12 = 17/12$

B. Subtraction.

1. Find a common denominator if necessary. (Fractions must have a common denominator before subtraction can be done.)

2. Subtract the numerator of the subtrahend from the numerator of the minuend and write the difference over the common denominator.

3. Reduce the fraction to its lowest terms.

4. Examples:

$$\begin{array}{r} 11/16 \\ 3/16 \\ \hline 8/16 \end{array} = 1/2 \qquad \begin{array}{r} 4/8 \\ 1/4 \\ \hline \\ \hline \end{array} \text{ change to } \begin{array}{r} 4/8 \\ 2/8 \\ \hline 2/8 \end{array} = 1/4$$

6/8 - 2/8 = 4/8 = 1/2

8/6 - 1/2 = 8/6 - 3/6 = 5/6

C. Multiplication.

1. Whole number times a fraction.

a. Give the whole number a denominator of 1.

b. Multiply the numerators of the fractions to obtain a numerator for the <u>product</u>.

c. Multiply the denominators of the fractions to obtain a denominator for the <u>product</u>.

d. Reduce the fraction to its lowest terms.

e. Examples:

4 X 1/4 = 4/1 X 1/4 = 4/4 = 1

3 X 3/6 = 3/1 X 3/6 = 9/6 = 1 3/6 = 1 1/2

2. Fraction times a fraction.

Follow rules 1b through 1d as stated above.

D. Division.

1. Whole number divided by a fraction or a fraction divided by a whole number.

a. Give the whole number a denominator of 1.

b. Invert (reverse positions of the numerical values of the numerator and the denominator) the divisor.

c. Multiply the fractions to obtain a <u>quotient</u>.

2. Fraction divided by a fraction.

a. Invert the divisor.

b. Multiply the fractions to obtain a <u>quotient</u>.

3. Examples:

$2 \div 1/4 = 2/1 \div 1/4 = 2/1 \times 4/1 = 8/1 = 8$

$1/2 \div 2 = 1/2 \div 2/1 = 1/2 \times 1/2 = 1/4$

$8/2 \div 2 = 8/2 \div 2/1 = 8/2 \times 1/2 = 8/4 = 2$

$1/4 \div 1/8 = 1/4 \times 8/1 = 8/4 = 2$

$8/16 \div 1/2 = 8/16 \times 2/1 = 16/16 = 1$

$1/8 \div 1/4 = 1/8 \times 4/1 = 4/8 = 1/2$

NOTETAKING SHEET 1.5.1N

LINEAR EQUATIONS

REFERENCES:

1. _Mathematics_, Vol. I, NAVPERS 10069C, 1966, Chapter 5, pp. 120-129.

2. _Mathematics_, Vol. III, NAVPERS 10073A, 1969, Chapters 11 & 12, pp. 162-177.

NOTETAKING OUTLINE

A. Definitions

1. Equation: A mathematical statement that two expressions are equal in value.

Linear Equation: An equation whose unknown quantities appear no more than once in each term, and only with the understood exponent of one.

B. Axioms and Their Uses

1. Axiom: A truth or fact that is self evident and needs no formal proof.

2. General axiom:

3. Uses of the axiom

C. Solving a Linear Equation Containing One Unknown

D. Simultaneous Solution

1. General Information

2. The substitution method

3. Addition and subtraction method

4. Matrix theory method

NOTETAKING SHEET 1.6.1N

FORMULA

REFERENCES:

1. <u>Mathematics</u>, Vol. 1, NAVPERS 10069-C, 1966, Chapter 14 pp 151-157.
2. <u>Basic Mathematics for Electronics</u>, Fifth Edition, Cooke, Adams, Dell; McGraw-Hill, 1982.

NOTETAKING OUTLINE

A. Definitions

1. Formula - A general fact, rule, principle, or law expressed as equation by the signs and symbols of algebra.

2. Dependent variable

3. Independent variable

4. Subscripts

B. Purpose of a Formula - To shorten a general fact, rule, principle, or law into a mathematical equation.

C. Evaluating Formulas (solving)

D. Changing the Subject of a Formula

E. Five step method for changing the subject of a formula

NOTETAKING SHEET 1.7.1N

SOURCE CHARACTERISTICS & VOLTAGE DIVIDERS

REFERENCES:

1. Basic Electricity NAVPERS 10086-B
Chapters 4 & 5.

2. Basic Mathematics for Electronics, Fifth Edition, Cooke, Adams, Dell; McGraw-Hill, 1982.

NOTETAKING OUTLINE

A. Source Characteristics

1. Internal Resistance

2. Solving for circuit values

3. Load resistance matches source resistance

4. Load resistance greater than source resistance

5. Load resistance less than source resistance

B. Voltage Dividers

1. Components

2. Negative and positive voltages

3. Bleeder resistor

4. Kirchhoff's law

5. Solving for total current in a voltage divider

6. Solving for circuit values in a voltage divider

NOTETAKING SHEET 1.8.1N

BRIDGE CIRCUITS

REFERENCES:

1. Basic Electricity, NAVPERS 10086-B, 1969, Chapter 15, pp. 251-253.

2. Shrader, Robert l., Electronic Communication, 1980, McGraw-Hill, Chapter 12, pp. 244.

3. Basic Mathematics for Electronics, Fifth Edition, Cooke, Adams, Dell; McGraw-Hill, 1982.

NOTETAKING OUTLINE

A. Definitions: Bridging - The shunting of one electrical circuit by another.

B. Balanced Bridge Circuit

C. Unbalanced Bridge Circuit

NOTETAKING SHEET 1.9.1N

CAPACITANCE AND RC TIME

REFERENCES:

1. Basic Electricity, NAVPERS 10086-B series.

2. Electronic Circuit Analysis, Vol. I, NAVAIR 00-80-T-79 Chapter 6.

NOTETAKING OUTLINE

A. General Information

1. Definitions

a. Capacitance -

b. Dielectric -

c. Dielectric Strength -

d. Dielectric Constant -

e. Working Voltage

2. Capacitor Voltage Ratings

3. Factors Affecting the Value of Capacitance

4. The Charge in Coulombs

B. Total Capacitance.

1. Series Circuits

2. Parallel Circuits

C. Electrostatic Action in a Capacitor.

D. Charging Capacitors in Series and Parallel Circuits.

1. Series Circuits

2. Parallel Circuits

E. Resistive and Capacitive (RC) Circuits.

1. Effective voltage (E_{eff})

2. Kirchhoff's law

F. RC Switching Circuits

INFORMATION SHEET 1.9.1I

CAPACITANCE AND RC TIME

INTRODUCTION

The purpose of this information sheet is to provide you with additional information pertaining to lesson 1.9. Use of this information sheet will enhance your knowledge of capacitance and RC time.

REFERENCES

1. Basic Electricity, NAVPERS 10086-B series.

2. Electronic Circuit Analysis, Vol. I, NAVAIR 00-80-T-79, Chapter 6.

INFORMATION

A. General

1. The function of many circuits in electronic equipment is determined by the action of a capacitor, either charging or discharging through a resistor. Therefore, it is evident that a thorough knowledge of this action is important and essential for proper understanding of electronic equipment.

2. At any instant of time, the current in an RC circuit will be equal to the voltage across the total resistance, at that instant divided by the total resistance. However, a voltage will be developed across a resistance only when current flows through it.

B. Kirchhoff's law

1. Kirchhoff's voltage law states in effect that the algebraic sum of all the voltage drops in a closed loop must, at any instant, equal zero. This may be used to determine the voltage across some component in a circuit when the volt-ages across all but that component are known. Figure 1 illustrates this.

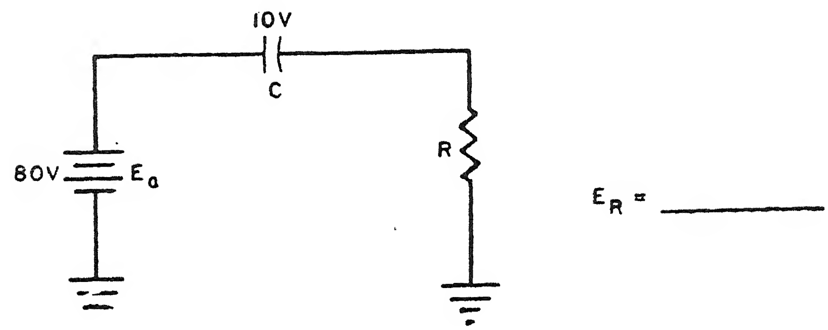


Figure 1

2. To find E_R, start at any point in the circuit and make a complete loop. The actual point of starting is unimportant as long as a complete loop is made. The direction of the loop is also unimportant as long as you go through all component parts in the same direction. Suppose in the example you start at ground and go in a clockwise direction, adding the voltages across the elements as you make the loop. In the example, you would have -80 + 10 = -70 volts. Therefore, you must have +70 volts across the resistor to make the sum of all voltages in the closed loop equal to zero.

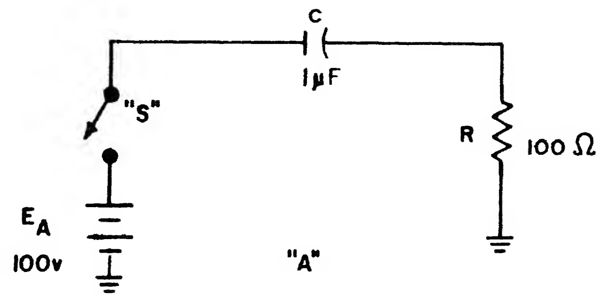
Rate of Charge

1. Last week you learned Q = CE, where Q is the charge on a capacitor in coulombs. Also, Q = IT where I is the current flowing in the circuit in amperes and T is the time the current is flowing in seconds.

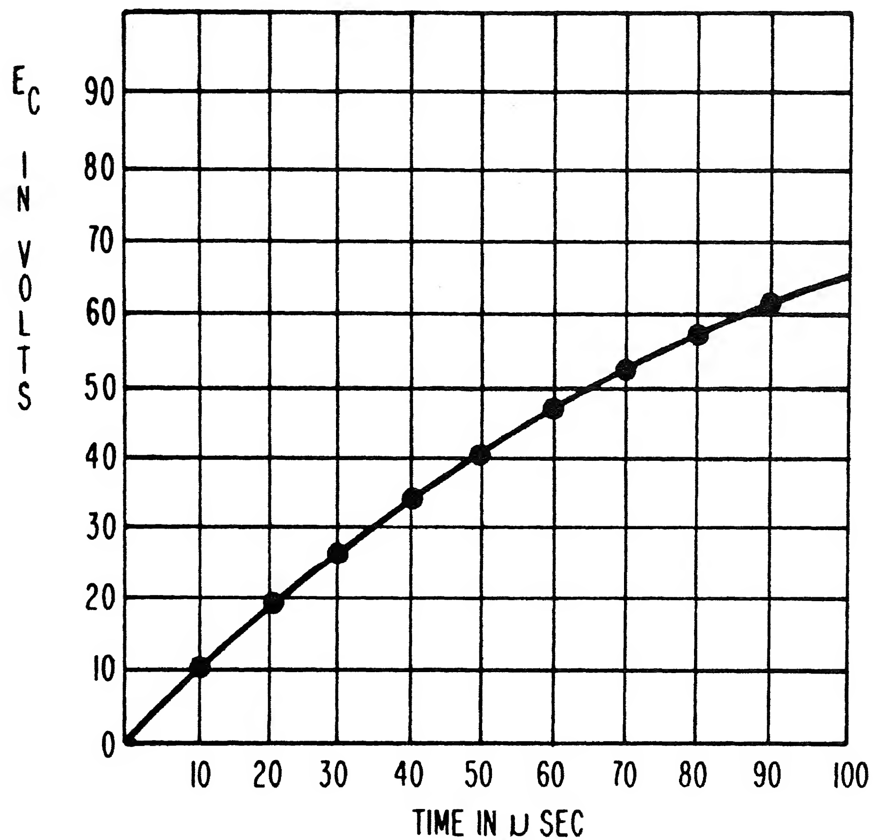
   Therefore, $IT = CE$ or $T = \frac{CE}{I} = C \cdot \frac{E}{I}$ and $(E/I = R)$ then $T = C \cdot R$ or more comonly stated $T = RC$.

Effective voltage

1. A term which is used in RC time quite frequently is effective voltage. By definition, effective voltage, as applied to an RC circuit, is defined as the voltage which is causing current to flow in a circuit. It can further be defined as the algebraic sum of all source voltages, both capacitor and battery or input, at the instant the circuit is considered closed. It will appear across the total resistance in the circuit. Figure 2 illustrates the charge of a capacitor.



"A"



"C"

TIME	E_R	I	E_C
0	100V	1A	0v
10μSEC	90v	.9A	10v
20μSEC	81v	.81A	19v
30μSEC	72.9v	.729A	27.1v
40μSEC	65.61v	.656A	34.39v
50μSEC	59.05v	.591A	40.95v
60μSEC	53.1AV	.531A	46.86v
70μSEC	47.83v	.478A	52.17v
80μSEC	43.05v	431A	56.59v
90μSEC	38.74v	.387A	61.26v
100μSEC	34.87v	.349A	65.13v

"B"

NOTE: THE VALUES ARE APPROXMATE.

Figure 2

2. At the first instant the switch "S" in figure 2A is closed, E_C is zero. By using Kirchhoff's law, the effective voltage, E_R, will be equal to 100 volts. This causes a current flow of 1A. By use of the formula, $E_C = \frac{IT}{C}$, the capacitor will change its charge by 10 volts in 10 μsec, assuming that the current flowing in the circuit is constant. The charge on the capacitor would be 10 volts.

3. This will reduce E_R to 90 volts and I to .9A. During the next 10 μsec, the capacitor will change its charge by 9 volts. This will charge the capacitor to 19V.

4. Continuing this process will produce the values given in the table in figure 2B. Plotting them will result in the curve in figure 2C.

E. <u>Capacitor charge</u>

1. From this, it can be noted that as the charge on the capacitor increases, the resistor voltage decreases by a corresponding amount. As the voltage across the resistor decreases, the current flowing in the circuit decreases, causing the rate of change of capacitor voltage to decrease.

2. If the switch "S" were left closed for 1,000 μsec, the capacitor in figure 2 would charge to E_{app} for all practical purposes.

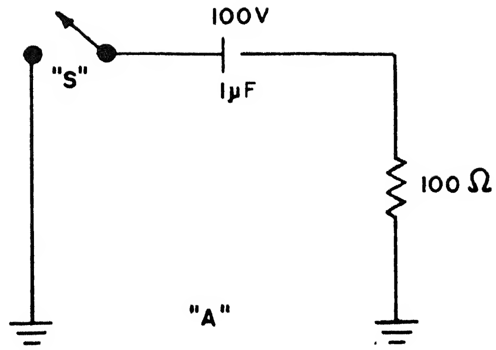
3. Increasing the capacity of the capacitor will cause the rate of change of the capacitor's charge to be decreased. The amount of current flowing in the circuit would be unchanged.

4. Increasing the resistance of the resistor will also decrease the rate of change of the capacitor's charge, since the effective voltage would be the same as before but the amount of current flow would be decreased.

F. <u>Capacitor discharge</u>

1. Figure 3 illustrates the discharge of a capacitor. At the first instant that "S" in figure 3A is closed, 100 volts appear across the resistor. By use of Ohm's law, the current flow is determined to be 1A. Therefore, in the first 10 μsec, the capacitor will change its charge by 10V. The charge on the capacitor would then be 90 volts.

2. Continuing this process will produce the values given in the table in figure 3B. Plotting these values produces the curve in figure 3C.



"B"

TIME	E_R	I	E_c	ΔE_c
0μ sec	100V	1A	100V	0
10μ sec	90V	.9A	90V	10V
20μ sec	81V	.81A	81V	19V
30μ sec	729V	.729A	72.9V	27.1V
40μ sec	65.61V	.656A	65.61V	34.39V
50μ	59.05V	.591A	59.05V	40.95V

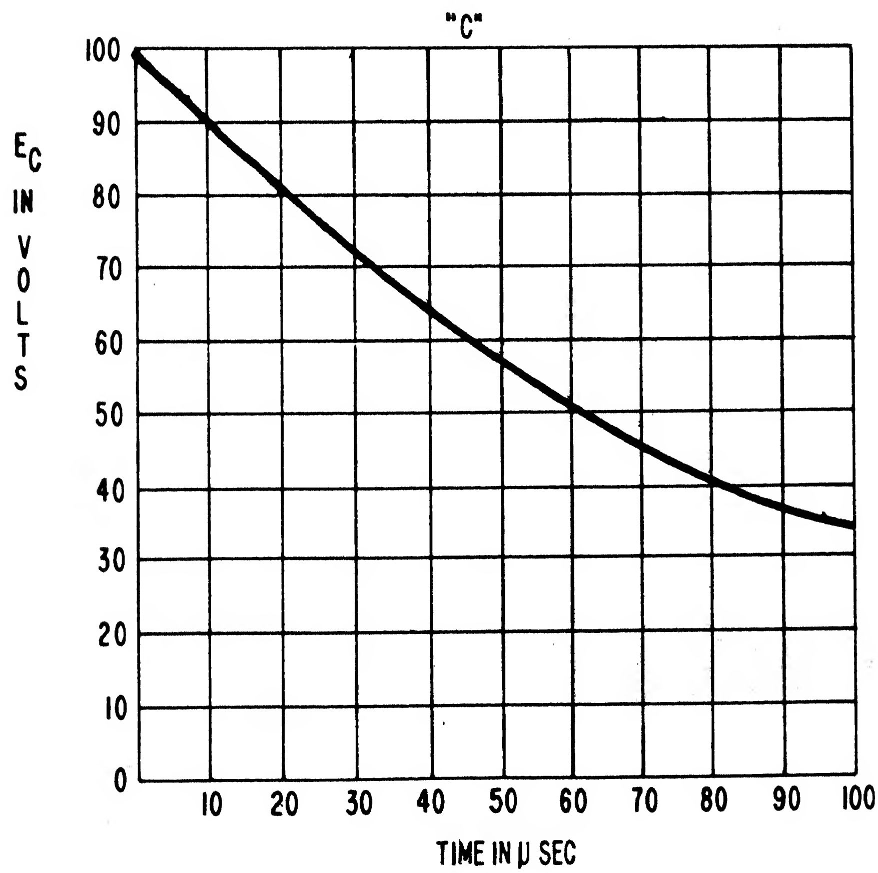


Figure 3.

3. Comparison of the curves in figures 3C and 2C shows that the curves labeled E_C are the opposite of each other. Figure 2 is the curve for the charge of a capacitor, while figure 3 is the curve for the discharge of a capacitor. The curves labeled ΔE are the same in both figures. The ΔE curve and the E_C curve are identical in figure 3. Therefore, the conclusion can be made that the percent of the effective voltage which a capacitor will change in a given number of RC time is always the same, regardless whether the capacitor is charging or discharging.

4. By use of epsilon formula, $E_C = E_{eff}\left(1 - \text{epsilon}\ \frac{-T}{RC}\right)$, the amount of charge on a capacitor may be determined for any length of time. This is plotted with RC time against percent of E_{eff} and is known as the Universal Time Constant Chart. A copy of this chart has been inserted as the last page of this information sheet.

G. RC time values

1. Some of the most commonly used values are:

   (a) In .1 RC, a capacitor will change its charge 10% of E_{eff}.

   (b) In 1 RC, a capacitor will change its charge 63% of E_{eff}.

   (c) In 2.3 RC, a capacitor will change its charge 90% of E_{eff}.

   (d) In 10 RC, a capacitor will change its charge 100% of E_{eff}.

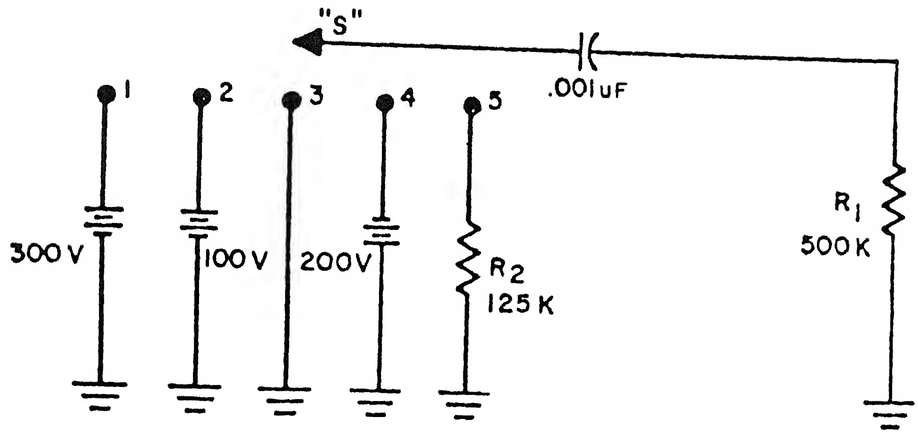
2. This information is very useful in solving problems. An example problem is shown in figure 4. The best method to solve such problems is by use of the following four steps:

   Step 1. Using Kirchhoff's law, combine E_C and E_{app} to find $E_{eff}(E_R)$.

   Step 2. Let the capacitor change its charge for time given.

   Step 3. Find the voltage left across the resistor.

   Step 4. Using Kirchhoff's law, combine E_{app} and E_R to find E_C.



Pos #	E_{eff}	Time	E_c	E_{R_1}	E_{R_2}
1	+300 V	1150 µsec	+270 V	+30 V	-
2	-170 V	500 µsec	+163 V	-63 V	-
3	-163 V	50 µsec	+146.7 V	-146.7 V	-
4	-346.7V	1150 µsec	-165.33 V	-34.67 V	-
5	+165.33 V	625 µsec	-61.33 V	+48.9 V	+12.4

Figure 4

3. The reason for using this procedure is that the direction of current flow and the polarity of E_R never changes for any set of conditions, while the polarity of the charge on the capacitor may change. Also, the voltage across the resistor always decreases, whether the capacitor is charging or discharging.

4. Assume that the switch is closed in position 1. The circuit is shown in figure 5A. Using the procedure outlined previously step 1 gives an E_{eff} of 300 volts. The RC time is 500 µsec, so the switch will be closed for 2.3 RC time. Step 2 is merely to give a sequence of operation. No actual work is done on this step. In 2.3 RC, the capacitor will change its charge by 90% of E_{eff}. This leaves 10% of E_{eff} or 30 volts across the resistor for step 3. Step 4 is shown in figure 5B and gives us an E_c of 270 volts.

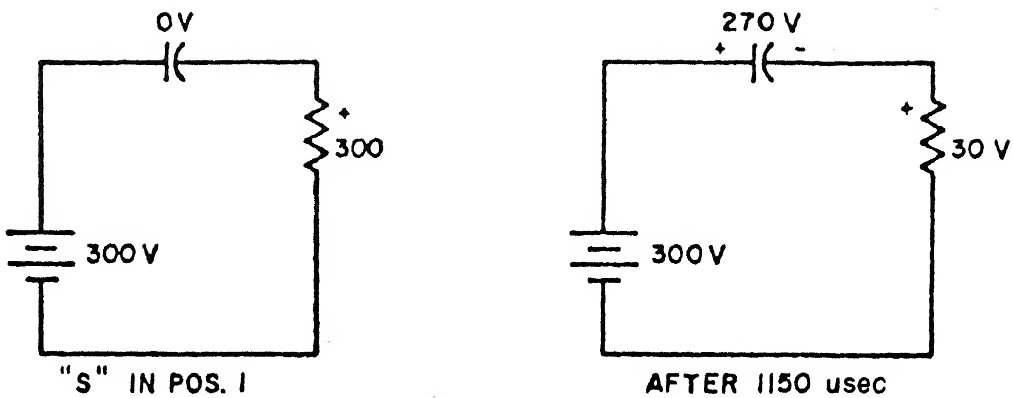


Figure 5

5. The switch is now thrown to position 2 in zero time. Since the capacitor cannot change its charge in zero time, we must carry over E_C with its proper polarity. However, the current in the circuit and the voltage across the resistor can change in zero time. We start back with step 1 in the procedure and work through step 4, since the conditions are now changed. Figure 6 shows the circuit in position 2.

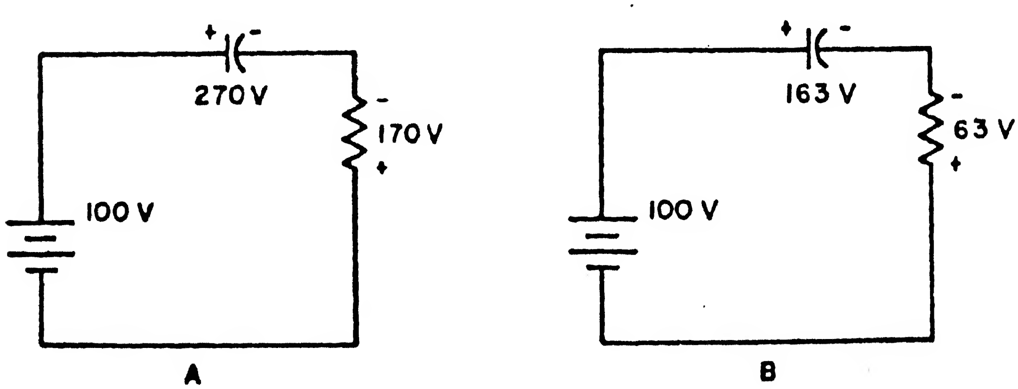


Figure 6

Step 1. E_{eff} = 170 V.

Step 2. Capacitor will change its charge for 1 RC.

Step 3. E_R = 37% of E_{eff} or 63 V.

Step 4. E_C = 163 V.

6. The switch is then thrown to position 3, taking only E_C with you. Refer to figure 7.

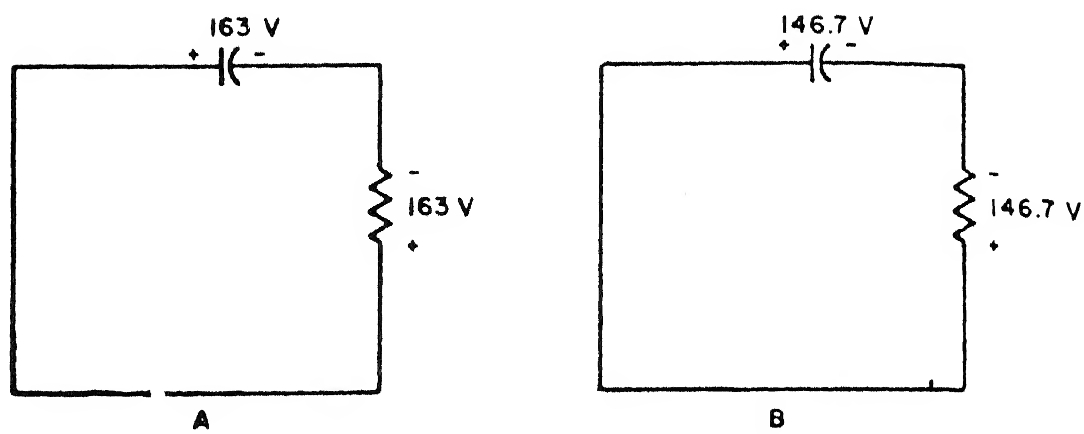


Figure 7

Step 1. E_{eff} = 163 V.

Step 2. Capacitor will change its charge for .1RC (10%)

Step 3. E_R = 90% of E_{eff} or 146.7 V.

Step 4. E_C 146.7 V.

7. The switch is now thrown to position 4. Refer to figure 8.

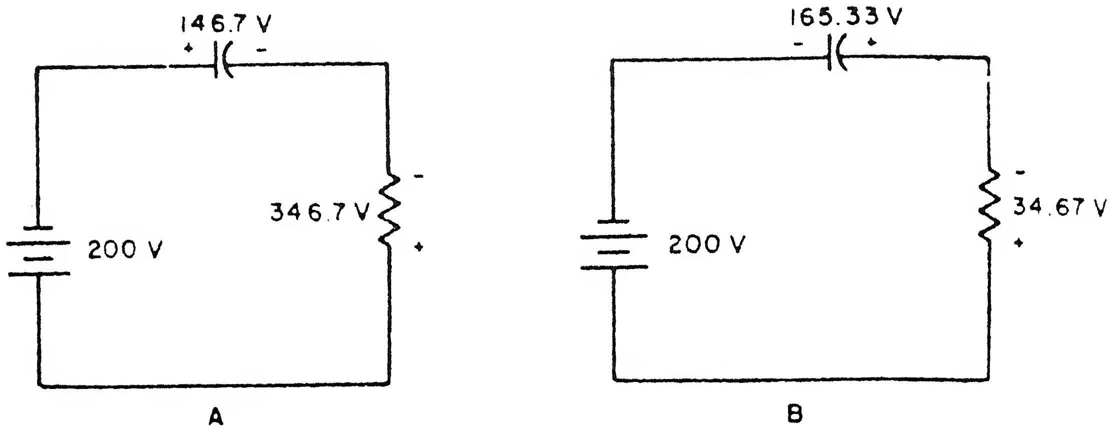


Figure 8

Step 1. E_{eff} = 346.7 V.

Step 2. Capacitor will change its charge for 2.3 RC (90%).

Step 3. E_R = 10% of E_{eff} or 34.67 volts.

Step 4. E_c = 165.33 volts.

8. The switch is now thrown to position 5. The RC time will increase, since another resistor will be in serie with R_1. The effective voltage will appear across the total resistance in the circuit. The voltage will divide across the individual resistors, proportional t their resistance. Refer to figure 9.

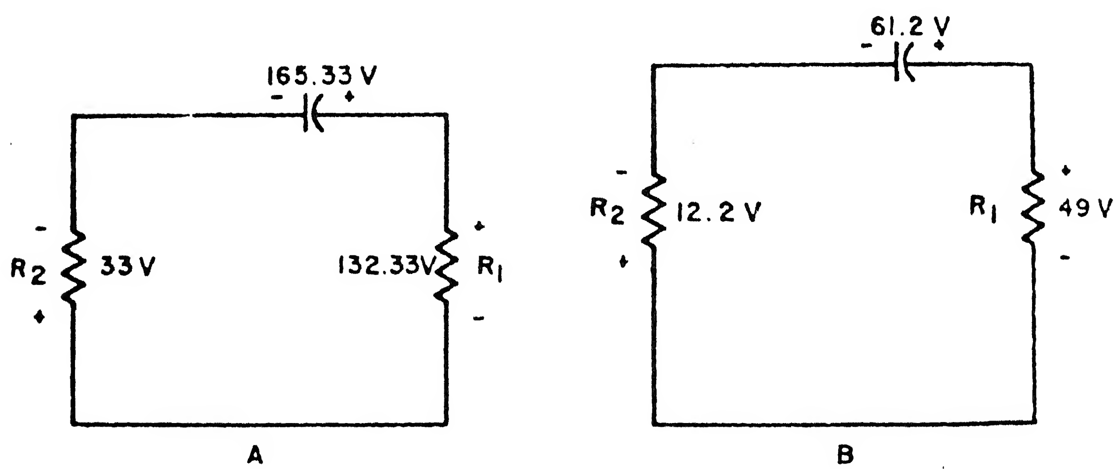


Figure 9

Step 1. $E_{eff} = 165.3$ V.

Step 2. Capacitor will change its charge for 1 RC (63%).

Step 3. E_R = 37% of E_{eff} or 61.2 V.

Step 4. $E_C = 61.2$ V.

H. Change of charge

1. Another type of problem which is often encountered is where the initial charge on a capacitor is known, and it is desired to know the time which it will take for a capacitor to change its charge to a given value. This can also be applied to the voltage across the resistor. In figure 10 an example of this is shown.

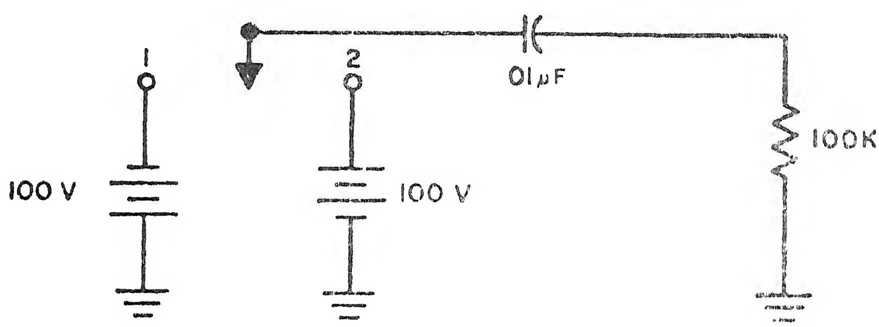


Figure 10

2. After 2300 µsec in position 1, switch to position 2. How long must the switch be in position 2 before the charge on the capacitor will be zero?
Answer: 670 µsec.

3. The problem is worked for position 1 by the four steps as used in the previous problem. Refer to figure 11.

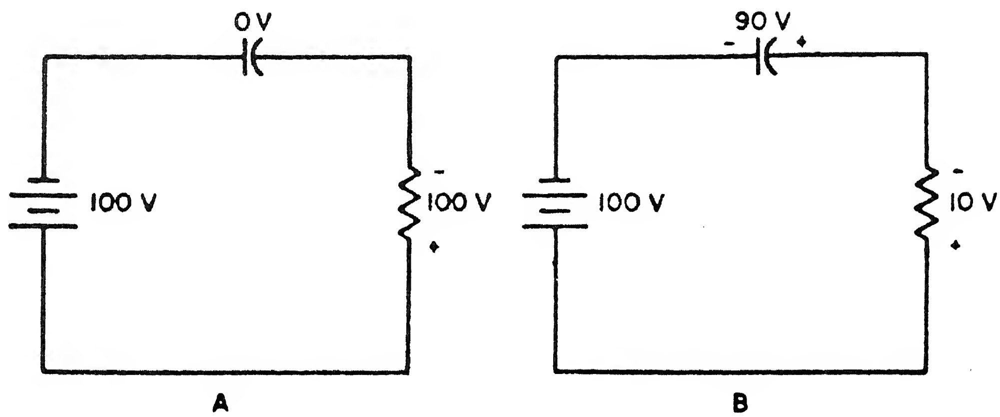


Figure 11

Step 1. E_{eff} = 100 V.

Step 2. Capacitor will change its charge for 2.3 RC (90%).

Step 3. E_R will be 10% of E_{eff} or 10V.

Step 4. E_c = 90 V.

4. The switch is then thrown to position 2. The effective voltage is then found as before. The amount of change of charge then is determined. The amount that the voltage across the resistor changes is the same as the amount which the capacitor will change its charge. The formula: percent of change of $E_c = \frac{\Delta E}{E_{eff}} \times 100$. Refer to figure 12.

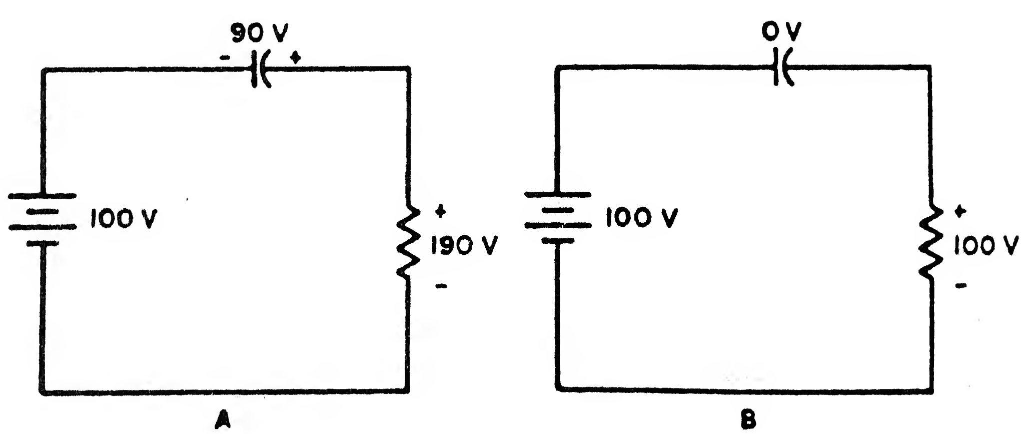


Figure 12

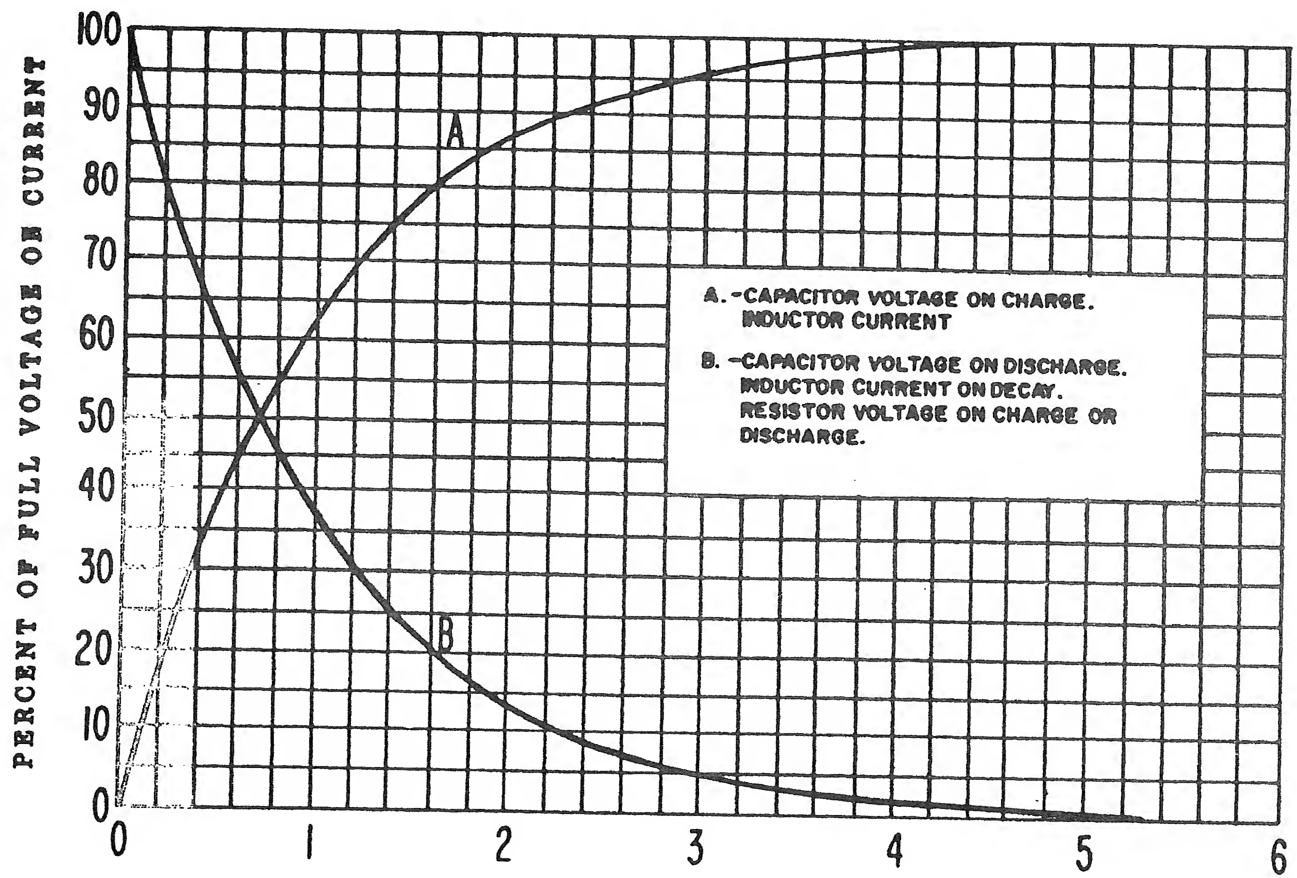
5. The effective voltage is 190 volts. The capacitor must change its charge 90 V; therefore, the capacitor must change its charge by 47.4% of E_{eff}. Going to the Universal Time Constant Chart, we see it takes .67 RC. The RC time is 1000 μsec; therefore, it takes 670 μsec for the capacitor charge to reach zero.

I. Definitions

1. Many times it is necessary to compare the RC time of a circuit to the longest or shortest portion of the applied waveform.

2. A long-RC circuit is defined as one where the RC time of a circuit is ten times (or greater) the longest portion of the input waveform. The waveform across the resistor will resemble the input waveform. There will be maximum distortion in the waveform across the capacitor. The longer the RC, the more pronounced these conditions will become.

3. A short-RC circuit is defined as one where the RC time of a circuit is one-tenth (or less) the shortest portion of the input waveform. Across the resistor, there will be maximum distortion, while across the capacitor, the waveform will resemble the input waveform.



TIME IN RC OR L/R

Figure 13

RC PERCENTAGE CHANGE TABLE

NO. RC	% Change	% Remain	No. RC	% Change	% Remain	No. RC	% Change	% Remain
.05	4.877	95.123	1.05	65.006	34.994	2.05	87.127	12.873
.10	9.516	90.484	1.10	66.713	33.287	2.10	87.754	12.246
.15	13.929	86.071	1.15	68.336	31.664	2.15	88.352	11.648
.20	18.127	81.873	1.20	69.881	30.119	2.20	88.920	11.080
.25	22.120	77.880	1.25	71.350	28.650	2.25	89.460	10.540
.30	25.918	74.082	1.30	72.747	27.253	2.30	89.974	10.026
.35	29.531	70.469	1.35	74.076	25.924	2.35	90.463	9.536
.40	32.968	67.032	1.40	75.340	24.660	2.40	90.928	9.072
.45	36.237	63.763	1.45	76.543	23.457	2.45	91.371	8.629
.50	39.347	60.653	1.50	77.677	22.313	2.50	91.792	8.208
.55	43.305	57.695	1.55	78.775	21.225	2.55	92.192	7.808
.60	45.119	54.881	1.60	79.810	20.190	2.60	92.573	7.427
.65	47.795	52.205	1.65	80.795	19.205	2.65	92.935	7.065
.70	50.341	49.659	1.70	81.732	18.268	2.70	93.279	6.721
.75	52.763	47.237	1.75	82.623	17.377	2.75	93.607	6.393
.80	55.067	44.933	1.80	83.470	16.530	2.80	93.919	6.081
.85	57.259	42.741	1.85	84.276	15.724	2.85	94.216	5.784
.90	59.343	40.657	1.90	85.046	14.957	2.90	94.498	5.502
.95	61.326	38.674	1.95	85.773	14.227	2.95	94.766	5.234
1.00	63.212	36.788	2.00	86.466	13.534	3.00	95.021	4.979

3.05	95.264	4.736	4.05	98.257	1.743	5.05	99.359	.641
3.10	95.495	4.505	4.10	98.343	1.657	5.10	99.390	.610
3.15	95.715	4.285	4.15	98.423	1.577	5.15	99.420	.580
3.20	95.924	4.076	4.20	98.500	1.500	5.20	99.448	.552
3.25	96.123	3.877	4.25	98.573	1.427	5.25	99.475	.525
3.30	96.312	3.688	4.30	98.643	1.357	5.30	99.501	.499
3.35	96.492	3.508	4.35	98.710	1.290	5.35	99.525	.475
3.40	96.663	3.337	4.40	98.773	1.227	5.40	99.548	.452
3.45	96.825	3.175	4.45	98.830	1.170	5.45	99.570	.430
3.50	96.980	3.020	4.50	98.889	1.111	5.50	99.591	.409
3.55	97.128	2.872	4.55	98.943	1.057	5.55	99.611	.389
3.60	97.268	2.732	4.60	98.998	1.005	5.60	99.630	.370
3.65	97.401	2.599	4.65	99.043	.957	5.65	99.648	.352
3.70	97.528	2.472	4.70	99.090	.910	5.70	99.665	.335
3.75	97.648	2.352	4.75	99.134	.866	5.75	99.681	.319
3.80	97.763	2.237	4.80	99.177	.823	5.80	99.697	.303
3.85	97.872	2.128	4.85	99.217	.783	5.85	99.712	.288
3.90	97.976	2.024	4.90	99.255	.745	5.90	99.726	.274
3.95	98.075	1.925	4.95	99.291	.709	5.95	99.739	.261
4.00	98.169	1.832	5.00	99.326	.674	6.00	99.752	.248

INFORMATION SHEET 1.10.1I

INDUCTANCE AND L/R TIME

INTRODUCTION

The purpose of this information sheet is to provide you with additional information pertaining to lesson 1.10. Use of this information sheet will enhance your knowledge of inductance and L/R time.

REFERENCES

1. Basic Electricity, NAVPERS 10086B-series

2. Electronics Communication, Shrader, Robert L., Fourth Edition, McGraw-Hill, 1980.

INFORMATION

A. General

1. The operation of L/R circuits is very similar to that of RC circuits. The inductor current in an L/R circuit rises exactly like the capacitors voltage.

2. Figure 1 shows the typical current and voltage curves produced in L/R circuits. When the switch is closed, the battery voltage is applied across resistor R and inductor L. Current attempts to flow but the inductor opposes this change in current by building up a counter emf that, at the initial instant, exactly equals the $E_{applied}$. The curves show that at the instant the switch is closed in the circuit, all the voltage is across L and no voltage across R.

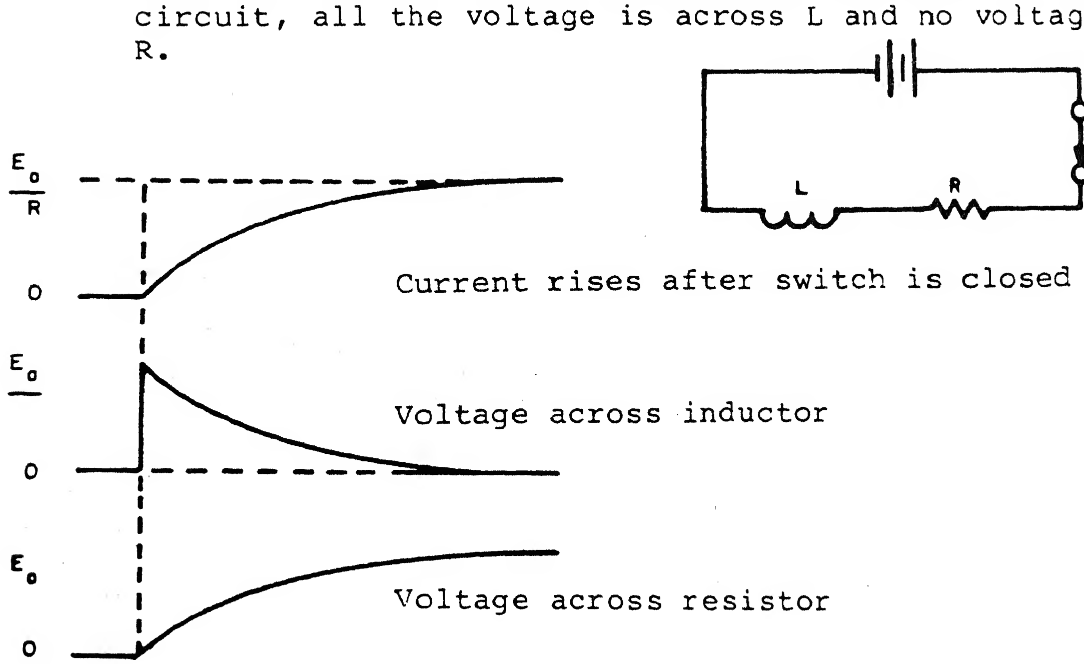


Figure 1

3. As current starts to flow, the voltage across the resistor starts to increase, the voltage across the inductor decreases. Under a state of steady conditions, the resistor is the only factor that limits the magnitude of current.

B. Kirchhoff's Law

Kirchhoff's voltage law states in effect that the <u>algebraic sum of all the voltage drops in a closed loop must, at any instant of time, equal zero</u>. This may be used to determine the voltage across some component in a circuit when the voltages across all but that component are known.

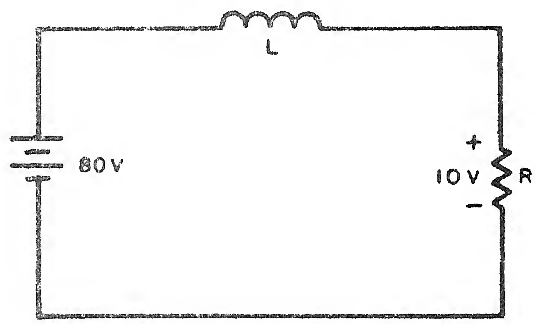


Figure 2

To find E_L, start at any point in the circuit and make a complete loop. The actual point of starting is unimportant as long as a complete loop is made. The direction of the loop is also unimportant as long as you go through all component parts in the same direction.

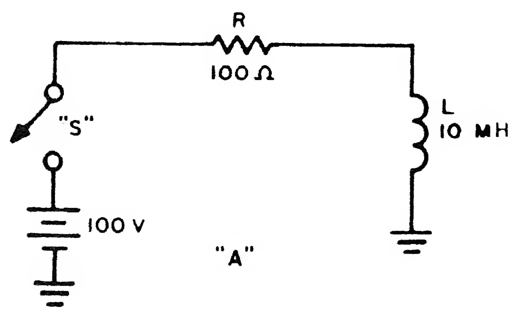
In figure 2, starting in the lower left-hand corner, you would have -80V +10V = -70V. Therefore, you must have +70V across the inductor to make the sum of all voltages equal zero.

C. Effective Voltage

A term which is used in L/R circuits quite frequently is effective voltage. By definition, effective voltage, as applied to an L/R circuit, is defined as the voltage which is able to cause current to flow in the circuit.

D. Inductor Charge

At the first instant the switch in figure 3A is closed, E_R is zero. By using Kirchhoff's voltage law, the effective voltage felt across the inductor (E_L will be equal to 100 volts). Current will start to flow, causing a voltage drop across the resistor. After 10 μsec the current will be equal to .1 amps causing a 10-volt drop across the resistor; this reduces the voltage on the inductor to 90 volts.



TIME	E_L	I	E_R
0	100 V	0	0 V
10 μSEC	90 V	.1 A	10 V
20 μSEC	81 V	.19 A	19 V
30 μSEC	72.9 V	.271 A	27.1 V
40 μSEC	65.61 V	.344 A	34.39 V
50 μSEC	59.05 V	.409 A	40.95 V
60 μSEC	55.14 V	.468 A	46.86 V
70 μSEC	47.83 V	.5217 A	52.17 V
80 μSEC	43.05 V	.5659 A	56.59 V
90 μSEC	38.74 V	.6126 A	61.26 V
100 μSEC	34.87 V	.6513 A	65.13 V

"B"

NOTE: THE VALUES ARE APPROXIMATE

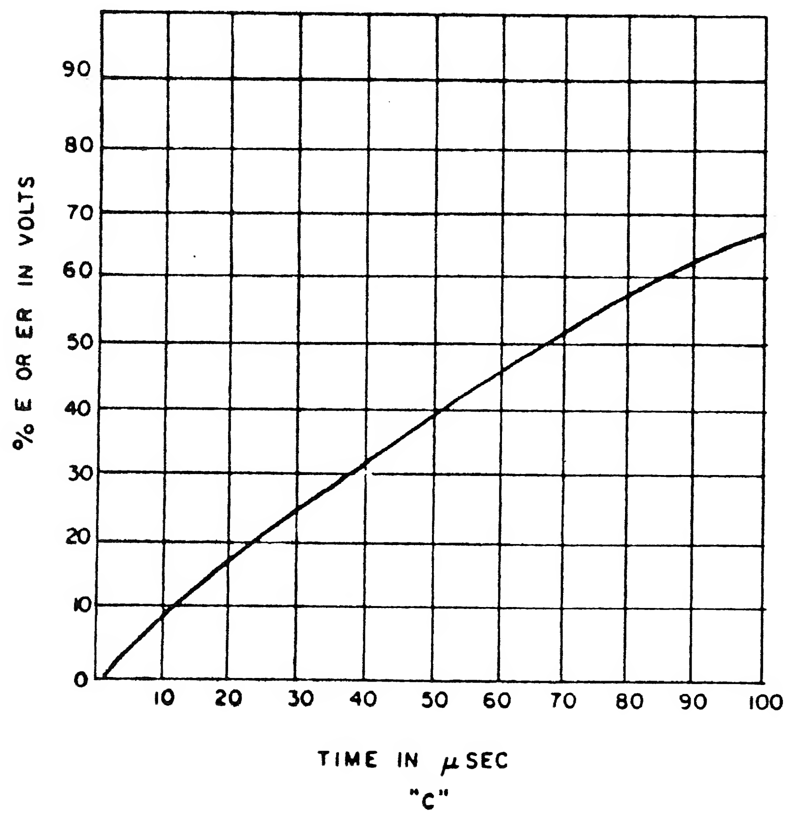
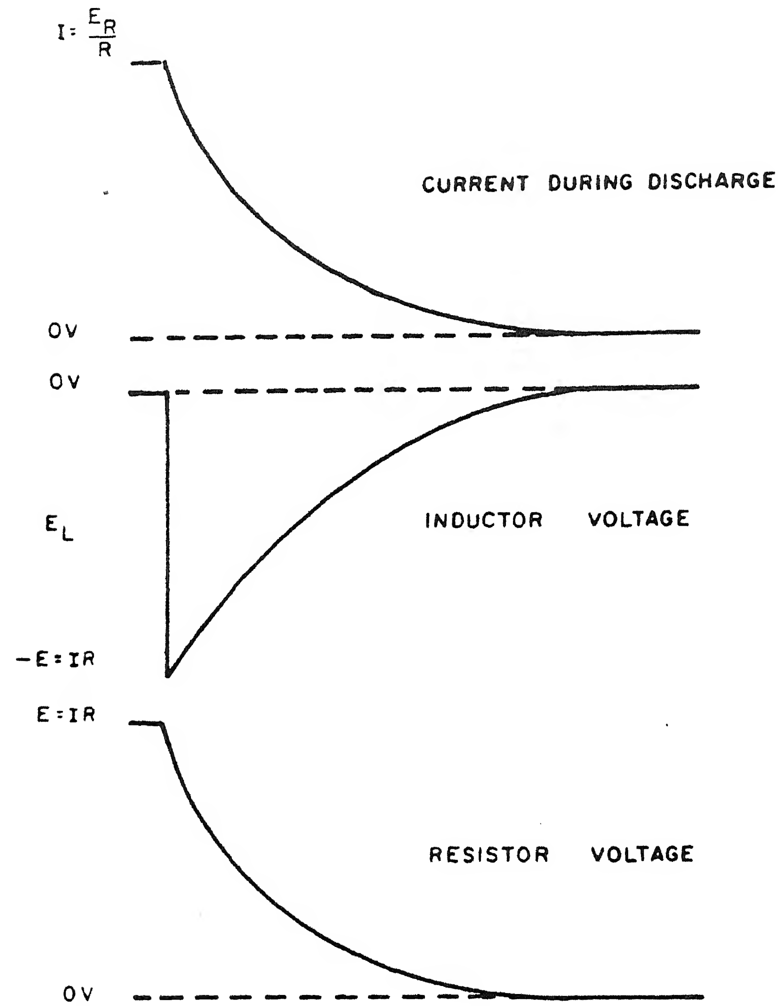


Figure 3



Voltage and current curves during collapse of inductor field

Figure 4

By the use of Kirchhoff's voltage law, $E_L + E_R = 0$

E. L/R Time Constants

An L/R time constant is defined as the time required for the current through an inductor to increase to 63.2% of its maximum value. The formula for the L/R time constant in seconds is $TC = \frac{L}{R}$

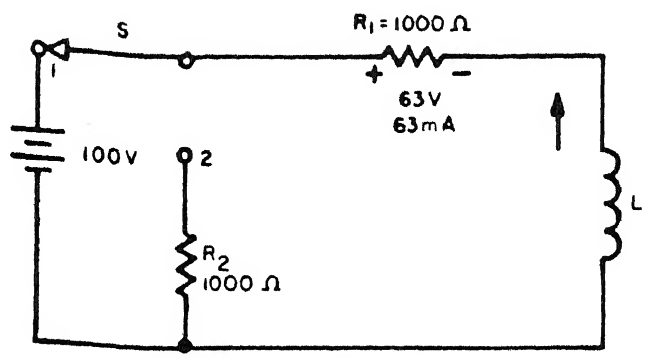
L = inductance in henrys

R = resistance in ohms.

The ratio $\frac{L}{R}$ also represents the time required for the resistor voltage to equal 63.2% of the applied voltage and the inductor voltage to equal 36.8% of the applied voltage.

F. Inductive Kick

1. The inductive kick is developed whenever the inductor becomes the source and the total circuit resistance is changed. As shown in figure 5A, the battery after 1 TC causes 63 mA of current flow in the circuit with the switch in position 1.



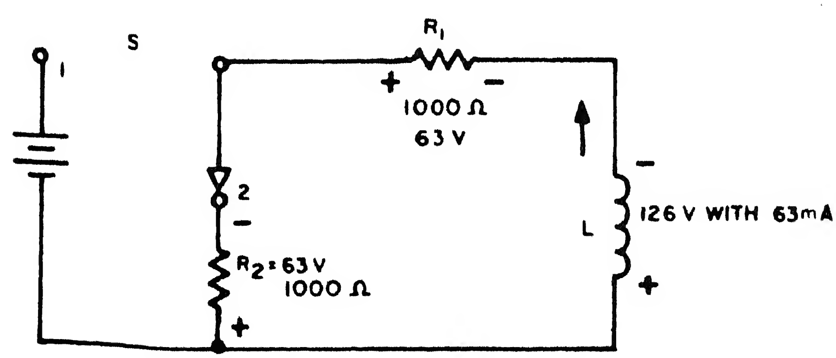


Figure 5

When the switch is changed to position 2 for the first instant the inductor opposes any change in current. There is still 63 mA of current flow as shown in figure 5B, which develops a 63 volt drop across R_1 and a 63 volt across R_2. Using Kirchhoff's voltage law

$$E_L + E_{R1} + E_{R2} = 0 \text{ volts}$$

$$E_L + 63v + 63V = 0 \text{ volts}$$

$$E_L = -126 \text{ volts}$$

G. LR Switching

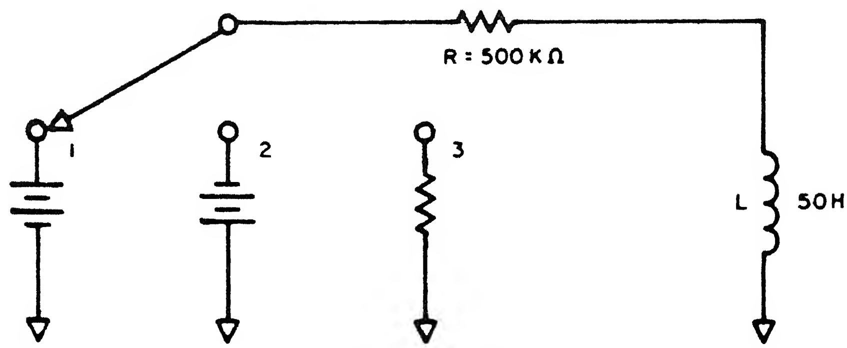


Figure 6

1. In solving LR switching problems, one method is the four-step method:

   Step 1. Using Kirchhoff's law, combine $E_{applied}$ and E_R to find E_{eff} (E_L).

   Step 2. Let the resistor voltage or circuit current make is change for the given time.

   Step 3. Find the voltage left across the inductor.

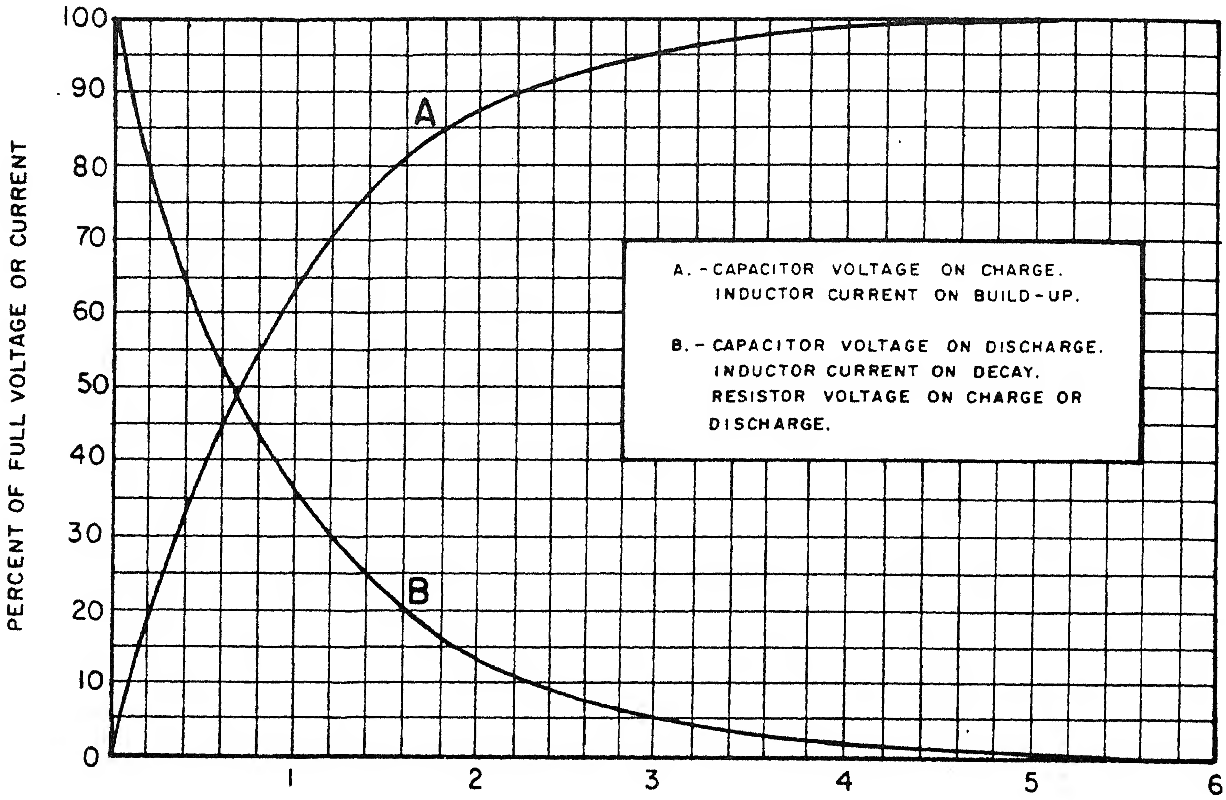
   Step 4. Using Kirchhoff's law, combine $E_{applied}$ and E_L to find E_R.

Position No.	$E_{effective}$	Time	E_L	E_{R1}	E_{R2}	I_T
1	100 V	100 μs	36.8V	63.2V	0	126.4 μA
2	-163.2V	230 μs	-13.32V	-86.68V	0	173.36 μA
3	173.32V	5 μs	156.03V	-78.015V	-78.015V	156.03 μA

2. Assume the switch is closed in Position 1. The circuit is shown in figure 7A. Using the procedure outlined previously, Step 1, given an E_{eff} of 100 V. The L/R time is 100 μsec, so the switch will be closed for one time constant.

RC PERCENTAGE CHANGE TABLE

NO. RC	% Change	% Remain	No. RC	% Change	% Remain	No. RC	% Change	% Remain
.05	4.877	95.123	1.05	65.006	34.994	2.05	87.127	12.873
.10	9.516	90.484	1.10	66.713	33.287	2.10	87.754	12.246
.15	13.929	86.071	1.15	68.336	31.664	2.15	88.352	11.648
.20	18.127	81.873	1.20	69.881	30.119	2.20	88.920	11.080
.25	22.120	77.880	1.25	71.350	28.650	2.25	89.460	10.540
.30	25.918	74.082	1.30	72.747	27.253	2.30	89.974	10.026
.35	29.531	70.469	1.35	74.076	25.924	2.35	90.463	9.536
.40	32.968	67.032	1.40	75.340	24.660	2.40	90.928	9.072
.45	36.237	63.763	1.45	76.543	23.457	2.45	91.371	8.629
.50	39.347	60.653	1.50	77.677	22.313	2.50	91.792	8.208
.55	43.305	57.695	1.55	78.775	21.225	2.55	92.192	7.808
.60	45.119	54.881	1.60	79.810	20.190	2.60	92.573	7.427
.65	47.795	52.205	1.65	80.795	19.205	2.65	92.935	7.065
.70	50.341	49.659	1.70	81.732	18.268	2.70	93.279	6.721
.75	52.763	47.237	1.75	82.623	17.377	2.75	93.607	6.393
.80	55.067	44.933	1.80	83.470	16.530	2.80	93.919	6.081
.85	57.259	42.741	1.85	84.276	15.724	2.85	94.216	5.784
.90	59.343	40.657	1.90	85.046	14.957	2.90	94.498	5.502
.95	61.326	38.674	1.95	85.773	14.227	2.95	94.766	5.234
1.00	63.212	36.788	2.00	86.466	13.534	3.00	95.021	4.979
3.05	95.264	4.736	4.05	98.257	1.743	5.05	99.359	.641
3.10	95.495	4.505	4.10	98.343	1.657	5.10	99.390	.610
3.15	95.715	4.285	4.15	98.423	1.577	5.15	99.420	.580
3.20	95.924	4.076	4.20	98.500	1.500	5.20	99.448	.552
3.25	96.123	3.877	4.25	98.573	1.427	5.25	99.475	.525
3.30	96.312	3.688	4.30	98.643	1.357	5.30	99.501	.499
3.35	96.492	3.508	4.35	98.710	1.290	5.35	99.525	.475
3.40	96.663	3.337	4.40	98.773	1.227	5.40	99.548	.452
3.45	96.825	3.175	4.45	98.830	1.170	5.45	99.570	.430
3.50	96.980	3.020	4.50	98.889	1.111	5.50	99.591	.409
3.55	97.128	2.872	4.55	98.943	1.057	5.55	99.611	.389
3.60	97.268	2.732	4.60	98.998	1.005	5.60	99.630	.370
3.65	97.401	2.599	4.65	99.043	.957	5.65	99.648	.352
3.70	97.528	2.472	4.70	99.090	.910	5.70	99.665	.335
3.75	97.648	2.352	4.75	99.134	.866	5.75	99.681	.319
3.80	97.763	2.237	4.80	99.177	.823	5.80	99.697	.303
3.85	97.872	2.128	4.85	99.217	.783	5.85	99.712	.288
3.90	97.976	2.024	4.90	99.255	.745	5.90	99.726	.274
3.95	98.075	1.925	4.95	99.291	.709	5.95	99.739	.261
4.00	98.169	1.832	5.00	99.326	.674	6.00	99.752	.248



TIME IN RC OR L/R

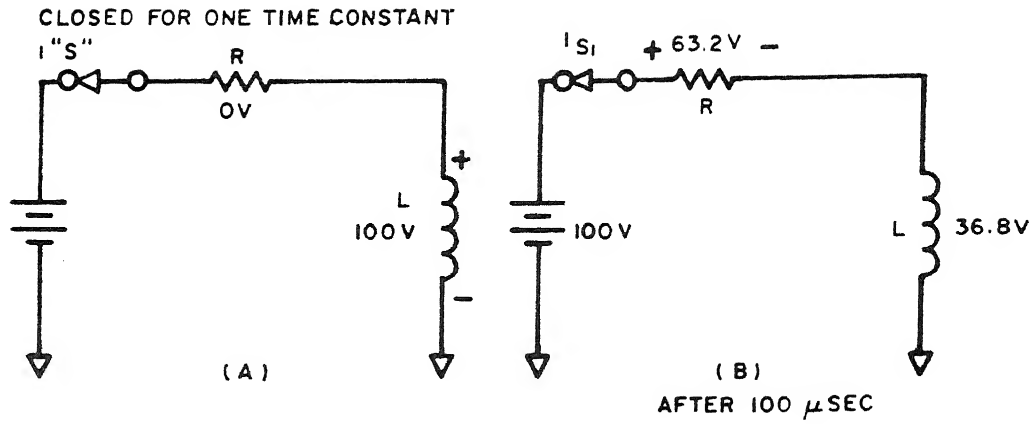


Figure 7

Now in step 2 no actual work is done. In one time constant the current will make a 63.2% change through the resistor developing 63.2% of $E_{applied}$ across the resistor. This leaves 36.8% of $E_{applied}$ across the inductor for step 3.

Step 4 is shown in figure 7B and gives 63.2V for E_R.

3. The switch is now switched to position #2. Since the inductor opposes any change in current, the current that was flowing through the inductor in position 1 tries to continue. Figure 8 shows this condition.

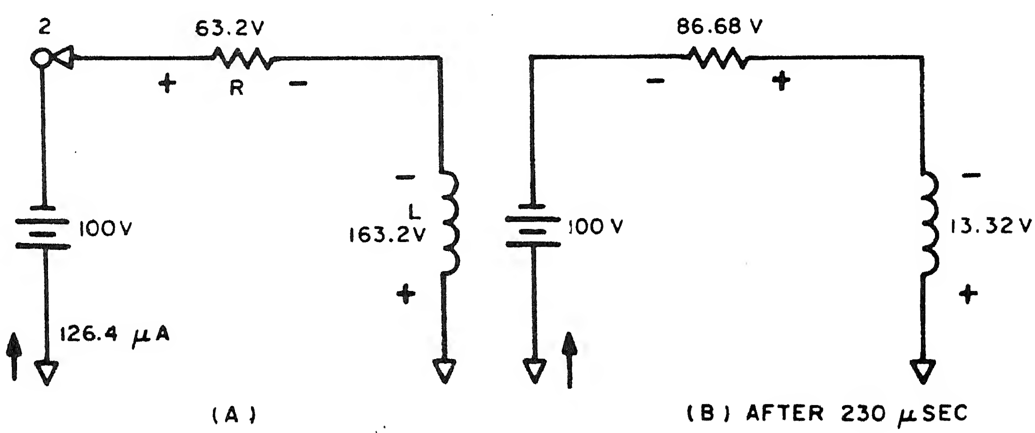


Figure 8

Now repeat step 1 through step 4 in solving for the values in position two.

Step 1 - E_{eff} = -163.2V

Step 2 - The circuit current will change in 2.3 time constants

Step 3 - E_L = -13.32V

Step 4 - E_R = -86.68V

4. The switch is now moved to position #3. In position #2 there were 173.36 μamps of current flow. The inductor opposes any change in this current, so for the first instant of time the current remains constant. Since this is a series circuit the current is flowing the same amount through both resistors, developing the same voltage on both resistors since they are equal size resistors. Figure 9A shows this condition,

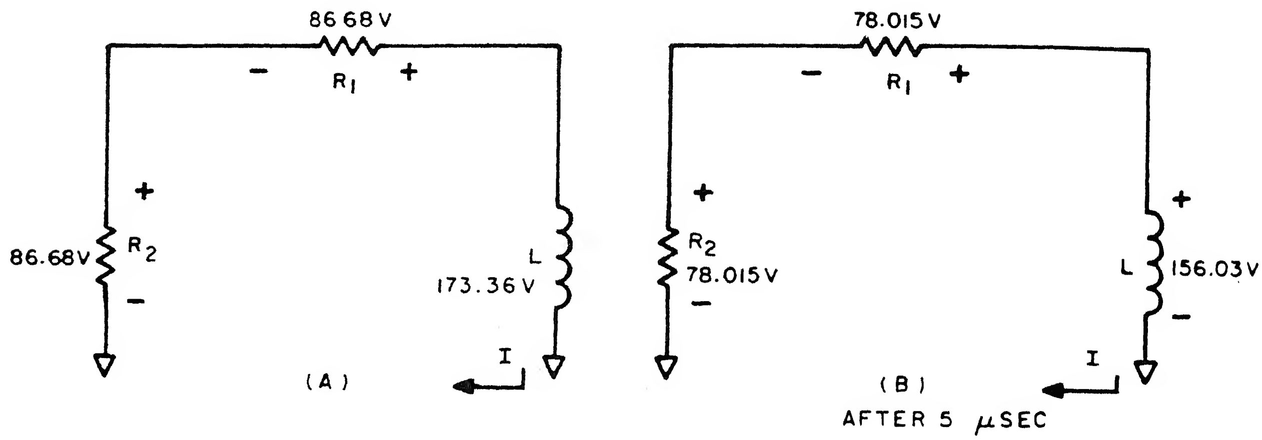


Figure 9

The inductor is now the source; its polarity is now opposite to what it was.

Repeat steps 1 through steps 4.

Step 1 - E_{eff} = 173.36V

Step 2 - The inductor changes its charge by 10%

Step 3 - E_L = 156.03V

Step 4 - E_{R1} = -78.015V

E_{R2} = 78.015V

NOTETAKING SHEET 1.10.1N

INDUCTANCE AND L/R TIME

REFERENCES:

1. Basic Electricity, NAVPERS 100868B-series.

2. Electronics Communications, 4th Edition, 1980.

NOTETAKING OUTLINE

A. General Information, Inductance (definition) - The characteristic of an electrical circuit that opposes any change in current.

B. Electromagnetic Action in an Inductance.

C. Build up and decay of Current in a L/R Circuit.

D. L/R Switching Circuits.

E. Total Inductance in Series & Parallel Circuits.

NOTETAKING SHEET 1.11.1N

TRIGONOMETRIC FUNCTIONS AND VECTOR ALGEBRA

REFERENCES:

1. Basic Mathematics for Electronics, Fifth Edition, Cooke, Adams, Dell; McGraw-Hill, 1982.

2. Technical Mathematics with Calculus, Rice H. S. and Knight R. M., McGraw Hill, 1975, Chapters 13 and 14.

3. Mathematics, Vol 1, NAVPERS 10069-C, Chapters 17 and 19.

NOTETAKING OUTLINE

A. Angles

1. Geometric definition - An angle is a measure of the difference in direction of two straight lines (line segments) which have a common starting point or point of intersection.

2. Angle description

3. Types of angles

B. Generated Angles

1. Description of generated angle

2. Positive and Negative generated angles

C. Rectangular Coordinates

1. Horizontal axis (r)

D. Vectors

1. Defined -

2. Vector quantity representation

3. Vector notation

4. Vector Algebra

5. Vector Graphic Analogy

E. Trigonometry

1. Defined

2. Right triangle

3. Trigonometric Functions

4. Solution of Right Triangles

NOTETAKING SHEET 1.12.1N

SERIES A-C CIRCUITS

References:

1. Basic Electricity, NAVPERS 10086-B series, Chapter 12.

2. Basic Mathematics for Electronics, Fifth Edition, Cooke, Adams, Dell; McGraw-Hill, 1982.

NOTETAKING OUTLINE

A. General Information (Definitions).

1. Alternating Current

2. Reactance -

3. Impedance -

B. Circuit Containing Pure Inductance.

1. Relationships of:

C. Comparing Series D-C & A-C Circuits.

D. Graphic Analysis of an A-C Series L/R Circuit.

E. Solving for Circuit Values in an A-C Series L/R Circuit.

F. Graphic Analysis of an A-C Series RC Circuit.

G. Solving Circuit Values in an A-C Series RC Circuit.

H. Graphic Analysis of an A-C Series LCR Circuit

I. Solving Circuit Values in an A-C Series LCR Circuit.

NOTETAKING SHEET 1.13.1N

PARALLEL A-C CIRCUITS

REFERENCES:

1. *Basic Electricity*, NAVPERS 10086-B series, Chapter 13.

2. *Basic Mathematics for Electronics*, Fifth Edition, Cooke, Adams, Dell; McGraw-Hill, 1982.

NOTETAKING OUTLINE

A. General Information.

B. Comparing D-C & A-C Parallel Circuits.

C. Computing Total Impedance in a Parallel A-C Circuit.

D. Graphic Analysis of a Parallel A-C Circuit (LR).

E. Solving for Circuit Values in a Parallel A-C Circuit (LR).

F. Graphic Analysis of a Parallel A-C Circuit (RC).

2. Vertical axis (j)

3. Origin

4. Standard position

G. Solving for Circuit Values in a Parallel A-C Circuit (RC)

H. Graphic Analysis of a Parallel A-C Circuit (LCR).

I. Solving for Circuit Values in a Parallel A-C Circuit (LCR).

J. Solution of Complex Parallel A-C Circuits.

K. Equivalent Series Circuit (ESC)

FORMULA SHEET UNIT I

I. BASIC FORMULAS

A. OHMS LAW $I = \frac{E}{R}$ $E = IR$ $R = \frac{E}{I}$

B. POWER $P = IE$ $P = I^2R$ $P = \frac{E^2}{R}$

C. RESISTORS IN PARALLEL

1. TWO RESISTORS $R_T = \frac{R_1R_2}{R_1 + R_2}$

2. MORE THAN TWO RESISTORS $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots$

D. RESISTORS IN SERIES $R_T = R_1 + R_2 + R_3 + \ldots\ldots\ldots$

E. REACTANCE $X_L = 2\pi fL$ $X_C = \frac{1}{2\pi fC}$

F. CAPACITANCE $C = \frac{KA}{d}$

II. BRIDGE CIRCUITS

A. UNKNOWN RESISTANCE $R_X = \frac{R_2R_3}{R_1}$

III. CAPACITANCE AND RC TIME

A. TOTAL CAPACITANCE

1. SERIES CIRCUITS

a. $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\ldots\ldots\ldots\ldots$

b. $C_T = \frac{(C_1)(C_2)}{(C_1) + (C_2)}$

III. CAPACITANCE AND RC TIME (CONT'D)

2. PARALLEL CIRCUITS

$C_T = C_1 + C_2 + C_3 + \ldots\ldots$

B. CHANGE IN COULOMBS

1. $Q = CE$

2. $Q_T = Q_{C1} + Q_{C2} + \ldots\ldots\ldots\ldots\ldots$ (for parallel circuits)

3. $Q_T = (C_T)(E)$ (for parallel circuits)

C. KIRCHKOFFS VOLTAGE LAW

$(E_a) + (E_C) + (E_R) = 0$

D. RC SWITCHING CIRCUITS

1. $T = RC$

2. $E_{effective} = E_R$

3. FIVE STEP METHOD

a. FIND E_{eff} $[\ (E_a) + (E_C) + (E_R) = 0\ ]$

b. FIND THE NUMBER OF TIME CONSTANTS

$\#TC = \dfrac{\text{switch time}}{\text{RC time}}$ then convert to % of change from chart

c. FIND THE CHANGE OF E_C

$\Delta E_C = (\%\Delta)(E_{eff})$

d. FIND $E_{C\text{-new}} = E_{C\text{-old}} \pm \Delta E_C$

e. FIND $E_{R\text{-new}} = [(E_a) + (E_{C\text{-new}}) + (E_R) = 0]$

IV. INDUCTANCE AND L/R TIME

A. TOTAL INDUCTANE

1. SERIES CIRCUITS

a. $L_T = L_1 + L_2 + L_3 + \ldots\ldots.$ (no coupling)

b. $L_T = L_1 + L_2 \pm 2M$ (with coupling)

2. PARALLEL CIRCUITS

a. $\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots\ldots.$

b. $L_T = \frac{L_1 \times L_2}{L_1 + L_2}$

B. INDUCTANCE (IN HENRIES) OF AN OPEN AIR COIL

$$L = \frac{1.257 \mu N^2 S}{10^8 L}$$

C. MUTUAL INDUCTANCE

$$M = K\sqrt{L_p L_s}$$

D. COEFFICIENT OF COUPLING

$$K = \sqrt{K_p K_s}$$

E. RATE OF CHANGE OF CURRENT

$$\frac{\Delta i}{\Delta t} = \frac{EL}{L} \qquad E_L = L \frac{\Delta i}{\Delta t}$$

F. L/R SWITCHING CIRUCITS

1. $T = L/R$

2. Find I_{Max}

3. Find the number of time constants

$$\#TC = \frac{\text{switch time}}{\text{L/R time}}$$ then convert from % of change from chart

4. $\Delta I = (\%\Delta)(I_{Max})$

5. $I_{new} = (I_{old}) \pm (\Delta I)$

6. Find $E_{R-new} = (R)(I_{new})$

7. Find $E_L = \left[(E_a) + (E_{R-new}) + (E_L) = 0\right]$

V. TRIGONOMETRIC FUNCTIONS

SINE COSINE TANGENT

$$\sin \theta = \frac{Opp}{Hyp}$$

$$\cos \theta = \frac{Adj}{Hyp}$$

$$\tan \theta = \frac{Opp}{Adj}$$

VI. SERIES AC CIRCUITS

$$P_f = \frac{P_T}{P_a} = \cos \theta \times 100 = \%$$

VII.

$$Z_T = \frac{Z_1 Z_2}{Z_1 + Z_2}$$

$$Z_T = \frac{E_a}{I_T}$$

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